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An Investigation of the Demonstration Method for Teaching Critical Thinking in Elementary School Science

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AN INVESTIGATION OF THE DEMONSTRATION METHOD FOR TEACHING CRITICAL THINKING IN ELEMENTARY SCHOOL SCIENCE

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

THE PROBLEM AND DEFINITIONS OF TERMS USED

Critical thinking is a valuable asset to all citizens of the present day tension-ridden world, just as it has been for centuries past and will continue to be far into the future. This learned ability to logically investigate material relating to a specific problem, sifting truths from non-truths and arriving at a definite conclusion from the available facts, is a skill everyone should possess. So many people, however, fail to even approach a workable ability to think critically, yet all the while struggling through countless everyday situations which require positive thinking. Too many meet these problem situations with an artificially conceived notion of thinking, then act upon the illogical conclusions resulting from their faulty reasoning. Because of its importance to everyone, this ability to think critically must take a definite position within the curriculum of the school, for only here can the mass of the general public of tomorrow obtain the necessary skills so important to them in thinking.

This ability should not be tied down to one specific area, as some learnings presently are, but must be made an integral part of each of the various educative areas available in the schools. The various factors involved in critical thinking are not by nature closely related to any one area, but are a part of all areas of learning. Nevertheless, specific techniques are necessary if one is to teach this critical thinking ability to students. The techniques used will vary with the teacher, the group of students and with the specific subject area being taught. The teaching of attitudes, for instance, necessary to critical thinking might be done one way in a social studies class and yet another way in English. And, yet, the facts and knowledge being taught are learned in addition to the attitudes and skills of critical thinking.

It is therefore possible to teach the skill of critical thinking in elementary science while still accomplishing the other objectives of the subject. Much of the information relating to the teaching of science on the elementary school level stresses the objective of teaching the students how to think. In fact, this objective can be found named in one way or another in nearly all present day lists of objectives for general education. However, little or nothing has been done be either educational researchers or classroom teachers in an effort to designate specific techniques for teaching the ability to think critically or to create tools with which to measure it.

I. THE PROBLEM

<u>Statement of the problem</u>. The purpose of this study

was to determine (1) the effectiveness of the demonstration method, as used in science on the elementary school level, in teaching the critical thinking ability; (2) whether a reliable testing device could be designed to measure critical thinking ability at the elementary school level; and (3) whether there exists a relationship between the mental ability of elementary school children and their ability to do critical thinking.

Importance of the study. In spite of the fact that many teachers say that one of the objectives of modern education is to teach children to think, few teachers actually make an effort to isolate this particular ability in terms of their teaching methods[1] and evaluation techniques.[2] Therefore, educators know little about the abilities of school children in thinking. Much attention in the past has been put upon the attainment of facts and skills. Until quite recently, little attention has been given to other more intangible objectives of education. Little research has been done in this field, with the exception of testing

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[1] National Society For The Study of Education, "Science Education in American Schools," Forty-Sixth Yearbook, Part I, (Chicago: The University of Chicago Press, 1947), p. 32.

[2] Bjarne R. Ullsvik, "An Attempt To Measure Critical Judgment," School Science and Mathematics, 49 (June, 1949), pp. 445-452.

devices available to measure personality traits, interests, attitudes and the like. The ability to think has been almost entirely neglected. In a review of past research in science teaching, Mallinson and Buck cite a specific need for research into classroom tests to measure critical thinking. They also assert that research is needed to determine the optimum use of various methods of teaching science.[3] This study was an attempt to partially fill the apparent voids in the elementary school science program.

II. DEFINITIONS OF THE TERMS USED

Demonstration. In science the terms demonstration and experiment are commonly used interchangeably. There exists, however, a definite difference between the two when they are used outside the science laboratory. A demonstration is usually defined as "a public showing and emphasizing of the salient merits, utility, efficiency, etc. of an article or product."[4] An experiment, on the other hand, is defined as "an operation undertaken to discover some unknown principle or effect, or to test some suggested truth, or to

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[3]George Grison Mallinson and Jacqueline V. Buck, "Some Implications and Practical Applications of Recent Research in Science Education: No. 2," School Science and Mathematics, 56 (May, 1956), pp. 357-369.

[4]Webster's New Collegiate Dictionary, (Springfield, Mass: G. & C. Merriam Co., 1956), p. 220.

demonstrate some known truth."[5] However, for the purposes of this study, the two terms were considered synonymous as far as their purpose was concerned. The difference was in the manner in which they were used. Whereas an experiment in the science laboratory is conducted and observed by one or two students, the demonstration is conducted by one person, usually the teacher, and is observed by the entire class. The demonstration may be used only to point out some important point, or it may be used for the same purpose as an experiment would be used.

Critical thinking. To specifically define such an intangible process as thinking is difficult. Present day attempts at a definition of thinking seem to be based upon the writings of John Dewey, who said that reflective thinking impels inquiry and aims at conclusions, while its origin is some perplexity, confusion or doubt.[6] While Dewey proposed that the two limits of thinking ". . . are a perplexed, troubled, or confused situation at the beginning and a cleared-up, unified, resolved situation at the close,"[7] he

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[5] Ibid., p. 291.

[6] John Dewey, How We Think, (Boston: D. C. Heath & Company, 1933), pp. 5-7.

[7] Ibid., pp. 106-107.

also outlined the process of thinking as being made up of five aspects:

(1) Suggestions, in which the mind leaps forward to a possible solution.
(2) An intellectualization of the difficulty or perplexity that has been felt (directly experienced) into a problem to be solved, a question for which the answer must be sought.
(3) The use of one suggestion after another as a leading idea, or hypothesis, to initiate and guide observation and other operations in collecting of factual material.
(4) The mental elaboration of the idea or supposition as an idea or supposition (reasoning, in the sense in which reasoning is a part, not the whole, of inference).
(5) Testing the hypothesis by overt or imaginative action.[8]

Other authors have expressed these same views. Such statements as "When problems are solved vicariously by the use of symbolic behavior, it is called _thinking_"[9] and "The problem-solving skills are those employed in reflective thinking"[10] substantiate this view. However, thinking cannot be defined as a list of specific steps to be conducted systematically. It is impossible to completely isolate thinking from its interrelated position within the individual's make-up. Skinner says that ". . . educators now tend to regard the

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[8] _Ibid_.

[9] Karl C. Garrison and J. Stanley Gray, _Educational Psychology_, (New York: Appleton-Century-Crofts, Inc., 1955), p. 336.

[10] National Society For The Study of Education, _loc. cit_.

thought processes as a part of the total behavior of the individual in the changing environment."[11] Based upon these expressions of the meaning of thinking, it can be seen that it is a process of problem-solving which arrives at a conclusion founded on existing facts and that it cannot be broken down into specific step-by-step procedures. Critical thinking is not a specific type of thinking, but it is rather thinking that requires the individual to be critical about the ideas that occur to him.[12] For the purpose of this investigation the definition proposed by Good was accepted. He defines critical thinking as "thinking that proceeds on the basis of careful evaluation of premises and evidence and comes to conclusions cautiously through the consideration of all pertinent factors."[13]

III. LIMITATIONS OF THE STUDY

No attempt was made in this study to evaluate the various extraneous factors which might contribute to the ability of a student to learn or improve the skill of

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[11] Charles E. Skinner (ed.), Elementary Educational Psychology, (Second Edition; New York: Prentice-Hall, Inc., 1950), p. 314.

[12] Dewey, op. cit., p. 16.

[13] Carter V. Good (ed.), Dictionary of Education, (First Edition; New York: McGraw-Hill Book Company, Inc., 1945), p. 424.

critical thinking. The home environment and present attitudes of the pupils were not investigated, nor was any attempt made to evaluate any learnings derived from study in any other subject areas. The study was confined to the teaching of science and the evaluation of critical thinking ability derived from this subject area. Only the mental ability of the pupils involved in the study was considered as a factor leading to the attainment of the desired skill.

IV. ORGANIZATION OF THE REMAINDER OF THE THESIS

Review of related literature. Although much has been written about thinking and testing, little has been related to a combination of the two for the elementary school level. An attempt was made to relate the available material to this level and to point out the lack of information about the teaching and evaluating of thinking.

Methods and procedures used. The demonstration method of teaching elementary school science was outlined in detail and related carefully to the factors involved in problem-solving. Each demonstration was selected from current literature and used within this outline as a method of teaching critical thinking. In order to evaluate the effectiveness of this demonstration method, a specific test of critical thinking for use in elementary school had to be devised. It was developed and then administered to several graduate students before being revised into its final form. The effectiveness of the test itself was determined after the initial administering to the experimental group. It was also given to a similar control group in order that its reliability could be more accurately determined. The experimental group consisted of twenty-five fifth and sixth grade children in the elementary school of Woodland, Washington during the school year of 1957-1958. During the first half of the school year the children were considered a control group and taught by regular methods, after having been tested at the beginning of the year. During the second half of the year, this same group was used on an experimental basis and taught with the demonstration method as a supplement to the regular methods. Testing was continued at the mid-point of the year and at the conclusion of the year.

<u>Results of the investigation</u>. A statistical comparison was made of the test scores made at the beginning of the year, at the middle, and at the end of the year. Based upon these figures, it was possible to determine the amount of growth evidenced by the group when it was taught by regular methods, and the amount of growth by the group when it was taught by the demonstration method. By this comparison, it was also possible to determine whether there was a significant

difference in the scores obtained during the use of the two teaching methods. Further, a statistical correlation was determined between the individual students' I.Q. and their initial test score and their gain according to the score obtained on the third test.

Summary and Interpretations. After briefly summarizing the complete investigation, it was possible to make some conclusions based upon the results obtained by the use of the test of critical thinking. These conclusions were apparent as being of importance both to classroom teachers of elementary school science and to educators who administer school programs or who conduct educational research. In light of the conclusions, it was also possible to make some general recommendations regarding the use of demonstrations for teaching critical thinking in the elementary school, as well as recommendations for further research in this particular area.

CHAPTER II

REVIEW OF RELATED LITERATURE

Critical thinking, especially at the elementary school level, has been somewhat neglected in recent years by educational researchers. Very little original work has been done with the appraising of this ability, though educators contend that it forms a vital part of the objectives of education. On the other hand, the use of demonstrations in elementary school science has been seriously advocated for many years, though there remains some doubt as to the practical use of demonstrations in the schools. However, the use of demonstrations for teaching a specific ability, such as critical thinking, has been relatively ignored. The gaining of a knowledge of facts and specific manual skills appears to have been the prime motive of science demonstrations in the classrooms of the past. Presented here are the few instances where demonstrations and critical thinking have been brought to the fore in teaching, as well as a brief survey of existing devices for the measurement of critical thinking.

I. THE DEMONSTRATION METHOD

Much has been written concerning the relative effectiveness and desirability of the various teaching methods in science from the elementary school level up through the college level. Many investigations were centered around the individual experiment or laboratory method versus the demonstration method. However, no conclusive evidence was found to support either method.[1] It should be noted here, however, that nearly all previous investigations have been concerned solely with the teaching of science facts and skills, rather than with the other more intangible objectives of science instruction. Nothing has been published about the effectiveness of either of these methods in the teaching of thinking at any level, though Reiner used a method of teaching cause and effect relationships that could be considered similar to the demonstration method.[2]

II. THE MEASUREMENT OF CRITICAL THINKING

Watson and Glaser have provided educators with what is probably the only standardized test of critical thinking available today.[3] However, it is designed for high school

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[1] Elwood D. Heiss, Ellsworth S. Obourn, and C. Wesley Hoffman, _Modern Methods and Materials For Teaching Science_, (New York: The MacMillan Company, 1940), pp. 62-65.

[2] William B. Reiner, "Evaluating Ability To Recognize Degrees of Cause and Effect Relationships," _Science Education_, 34 (February, 1950), pp. 15-28.

[3] Goodwin Watson and Edward Maynard Glaser, "Watson-Glaser Critical Thinking Appraisal," (New York: World Book Company, 1952).

and college students and adults. It is not available in any form for use in the elementary school. Nevertheless, it is one guide to the measurement of critical thinking. The test does not follow the outlines of any particular subject matter, but uses material common to all areas. It is divided into four parts, each designed to test a different aspect of critical thinking. In the field of high school social studies Wrightstone also has developed a measurement of critical thinking.[4]

Noll devised a test of scientific thinking some years back. It purported to measure such things as open-mindedness, intellectual honesty, criticalness, accuracy, and the habit of looking for true cause and effect relationships. It was used for high school students mostly.[5] However, in a separate study, Blair administered the test to sixteen college science professors and on the basis of their responses concluded that Noll's test was in some respects invalid.[6] In more recent times, Dunning designed a high school and college

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[4] J. W. Wrightstone, "Cooperative Test of Social Studies Abilities," (New York: Cooperative Test Service, 1936).

[5] Victor H. Noll, "Measuring Scientific Thinking," The Teachers College Record, 35 (May, 1934), pp. 685-693.

[6] Glenn M. Blair, "The Validity of the Noll Test of Scientific Thinking," The Journal of Educational Psychology, 31 (January, 1940), pp. 53-59.

level test of critical thinking.[7]

On the junior high school level, Reiner and Teichman have devised and administered tests of critical thinking. Reiner used an experimental group of ninth grade students, to whom specific cause and effect relationships were taught. This group made a significantly higher score on the test than did the control group, which did not receive special instruction.[8] Teichman administered a similar test to about 550 ninth grade students in science. He concluded that there is a direct relationship between mental ability and reading ability and the ability of a student to make conclusions. However, his study tended to show that neither mental ability nor reading ability seem to have much affect on the ability of students to improve the skill of making conclusions.[9]

Hyram also did some research in the teaching of critical thinking on the junior high school level. He taught the specific principles of logical thinking to seventh and eighth graders and concluded that this method

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[7]Gordon M. Dunning, "Evaluation of Critical Thinking," Science Education, 38 (April, 1954), pp. 191-211.

[8]Reiner, *loc. cit.*

[9]Louis Teichman, "The Ability of Science Students To Make Conclusions," Science Education, 28 (December, 1944), pp. 268-279.

of teaching critical thinking was effective, since there was a very significant gain in critical thinking ability of the experimental group over the control group of students. He also devised his own test of critical thinking for use at that particular level.[10]

On the elementary school level, Croxton conducted a study which seemed to indicate that many children in the primary, intermediate and junior high school levels are capable of generalizing. His study also seemed to show that junior high school students do not possess a markedly superior ability to generalize in comparison with elementary students.[11]

McLarney investigated the ability of elementary school students to do critical thinking in social studies. He designed a test to measure the attitudes of the students towards the people of other countries.[12]

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[10] George H. Hyram, "An Experiment in Developing Critical Thinking in Children," Journal of Experimental Education, 26 (December, 1957), pp. 125-132.

[11] W. C. Croxton, "Pupils' Ability To Generalize," School Science and Mathematics, 36 (June, 1936), pp. 627-634.

[12] Donald F. McLarney, "A Study of Change in Student's Critical Thinking in the Social Studies As Related To a Modification of the Curriculum" (unpublished Master's thesis, Central Washington College of Education, Ellensburg, 1955).

CHAPTER III

METHODS AND PROCEDURES USED

Development of a specific procedure to follow in the carrying out of the experimentation was necessary in order that the findings of the study be as accurate as possible. It was also essential to develop the actual method used to teach the critical thinking ability. A method of evaluating the results of the study was also necessary to complete the investigation.

I. THE PROCEDURE

Description of the student group. The experimental group consisted of twenty-five fifth and sixth grade students in a self-contained classroom of the elementary school in Woodland, Washington during the school year 1957-1958. No effort was made to handpick the group. The students were assigned to the class as a result of the normal distribution of students in the school. The investigator of this study was the regular classroom teacher for the group. The students were an ordinary group in nearly all respects. Normal administrative procedures resulted in the class containing both fifth and sixth grade students. However, no differentiation was made between the two grades in the teaching of science or the conducting of this study. The mental ability of the group is shown in Table I, page 18. Based upon this data, the group was considered to be a typical, normal elementary school class. The average I.Q. of the entire group was 102.36, placing it within the area considered normal. The nine fifth grade students possessed an average I.Q. of 113, while the sixth graders had an average I. Q. of 95. The range of I.Q.'s in the combined group was 64, with a low of 72 and a high of 135. There were six boys and three girls in the fifth grade group and twelve boys and four girls in the sixth grade group.

Time involved in the study. The entire investigation took place during a normal school year of 180 teaching days. However, the year was divided into two periods of identical length. The first half of the year the class was used as a control group, and during the second half of the year the class was used as an experimental group.

Testing schedule. Evaluation of the results of the investigation was based upon the scores obtained during three separate testings of the student group. An initial testing was conducted during the first week of school in September. The purpose of this testing was to establish the initial level of accomplishment of the group. The second testing was done at the half-way mark of the year to determine growth to that point. The third testing was completed

TABLE I

INTELLIGENCE QUOTIENTS OF PUPILS

IN EXPERIMENTAL GROUP

Students	Sex	I.Q.
1	F	72
2	M	109
3	M	99
4	M	120
5	M	103
6	M	104
7	M	104
8	M	92
9	M	83
10	M	101
11	F	109
12	F	115
13	M	89
14	F	91
15	M	95
16	M	99
17	M	111
18	F	113
19	F	91
20	M	95
21	M	87
22	M	119
23	M	115
24	F	135
25	M	108

at the end of the year in May to obtain scores showing total growth during the year and growth since the second testing.

Teaching methodology. As explained above, the class of students was first used as a control group during the first half of the school year. During this time the science instruction was given using regular methods of teaching. Individual and group reading, class discussion, individual preparation of reports, individual experimentation, and individual and group construction projects were all used as methods of teaching the science work during that period. The second half of the year the students were used as an experimental group. The regular methods of teaching were continued during this time, but were supplemented by the use of the demonstration method of teaching. The use of the demonstration in the teaching of science was the only variable introduced into the study. However, due to the nature of the investigation, the subject content of the science work differed during the two periods of time. An outline of the work studied by the students during the two semesters is listed in Appendix A.

II. DEMONSTRATIONS

Selection. Demonstrations used in the conducting of this investigation were selected from those available in current literature on science teaching, as well as those unpublished demonstrations developed by the investigator and other individuals with whom he has worked. Criteria for the selection of a demonstration followed generally these points: (1) Is the demonstration pertinent to the material being studied? (2) Is the demonstration suitable for the age level of the students? (3) Are the materials used in the demonstration simple? (4) Is the process to be demonstrated sufficiently simplified? (5) Is the demonstration short enough to be used during a normal class period and short enough to maintain student interest throughout its presentation? (6) Does the demonstration ably demonstrate an important concept rather than just provide entertainment for the children?

Method of presentation. All demonstrations used in this study were presented in a similar manner. Complete preparation by the teacher was accomplished prior to the presentation of each demonstration to insure that it would be presented smoothly. Before any demonstration was presented to the students, a definite problem was agreed upon. This problem, realized as such by the students, was written on the chalkboard and particular care was taken to insure that each student thoroughly understood the problem, including the meanings of the words used in writing the problem.

Then the carefully selected demonstration was presented to the class. The particular features of the demonstration were explained by the teacher and all pieces of equipment were carefully related to real-life situations prior to the actual performance of the demonstration. Explanation of everything that occurred during the demonstration was provided by the teacher during the presentation. Special care was taken to conduct the demonstration in accordance with the specific directions and at a slow enough rate of speed for the children to understand.

Following the demonstration, class discussion brought out its salient points and showed how it provided a solution to the problem written on the chalkboard at the beginning. The teacher led the discussion by asking such questions as: What was done in the demonstration? What happened during the demonstration? What did the demonstration show? How did the demonstration help to solve the problem? In what other ways could be problem have been solved? How is this new information shown in the demonstration related to everyday living?

In some cases, the students decided that another demonstration might show the solution to the problem more simply, or might provide better understanding of the problem by some members of the group. In other cases, the students thought it wise to repeat the demonstration in order that important phases might be more fully developed. This same information was obtained by the teacher at times after evaluating the discussion by the students following the original demonstration. Written reports of some of the demonstrations were prepared by the students. These reports outlined the demonstration, explaining what took place and what the demonstration showed. Learnings from the demonstration were listed and suggestions for improving the demonstration or substituting another for it were also welcomed by the teacher. A list of the demonstrations actually presented is provided in Appendix B.

III. EVALUATION

Test of critical thinking. In order to evaluate the effectiveness of the demonstration method of teaching critical thinking, a test had to be devised. Since no test of this type existed, the evaluation instrument used in this study was constructed entirely for this particular investigation. Even though the test is original, it was based upon work done previously at the junior high school level by Teichman[1] and Reiner.[2] In addition, eight items were used

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[1] Louis Teichman, "The Ability of Science Students To Make Conclusions," Science Education, 28 (December, 1944), pp. 268-279.

[2] William B. Reiner, "Evaluating Ability to Recognize Degrees of Cause and Effect Relationships," Science Education, 34 (February, 1950), pp. 15-28.

in this test that were also used by Teichman[3] in his testing device. A copy of this test may be found in Appendix C.

Development of the test. Using an outline of the topics to be taught in science during the investigation period as a basis of subject matter, the preliminary test was constructed. It contained forty-nine multiple-choice type items. This test was then administered to a group of twenty-six graduate students at Central Washington College of Education during the summer quarter of 1957. The test was also shown to three professors, two in the Education and Psychology Department and one in the Science Department, who generally approved of the test. On the basis of the responses of the graduate students to the test items, as well as the reliability index and the item difficulty index of the preliminary test, a new test was constructed. This new test was essentially the same as the first one except that it contained fifty test items, and several of the original items were re-written for clarity. The location of many of the items in the test was also revised. The second test was the one used in this study.

Test effectiveness. There are many methods of determining the effectiveness of a particular testing device.

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[3]Teichman, *loc. cit.*

However, regardless of the method used, the determination is still only relative. Whether a testing device is valid depends upon the validity of the instrument used to determine its validity. Each of the methods of determining a test's reliability possesses known limitations. However, a test that meets more than one requirement of reliability can be said to be relatively effective, at least enough for present use until a better evaluating device can be found. The test used in this investigation appears to be effective, based upon the information available.

The preliminary test devised for this investigation had a reliability index of .927, computed by the split-half method and the Spearman-Brown Prophecy Formula. The difficulty index of the preliminary test ranged from .14 to 1.00, with an average difficulty index for all items of .80. These figures were a result of administering the test to a group of twenty-six college graduate students, all school teachers.

The final test, as used in this investigation, yielded a reliability index of .932. This figure was based upon the results of a special administering of the test to a group of twenty-eight sixth grade students at a week's interval. The reliability index was computed by determining the correlation of the results of the two testings. The raw scores obtained in these two testings, as well as a frequency distribution of these scores, can be found in Appendix D. However, the limitation of this method of determining the reliability of a test is recognized as producing a very high coefficient. In order to determine a more accurate reliability of the test, an index based upon the first testing of the experimental group was computed using the split-half method and the Spearman-Brown Prophecy Formula. This computation resulted in a reliability index of .975. The split-half method of determining reliability has the limitation of the halves of the test usually not being equal. However, a high coefficient with both methods tends to indicate a test of reasonably high reliability.

An item difficulty index was computed on the basis of the first test given at the beginning of the year to the control group. The index of difficulty for the individual fifty items in the test ranged from a difficulty index of .08 to a difficulty index of .96, with a mean difficulty index of .51.

CHAPTER IV

RESULTS OF THE STUDY

The results of this study were obtained from the various test scores of the students in the control and experimental groups. Additional findings resulted from correlations between these test scores and the students' I.Q. scores. Classroom participation during the study also resulted in some indications from the students as to their learnings.

I. DEMONSTRATIONS

Incidental learning. In the course of the study, many demonstrations were presented to the group. These demonstrations promoted more interest in the study of science and aided the poorer students in more fully understanding the principles involved. Occasionally, circumstances offered the students excellent opportunities for further research and real critical thinking. In some cases, demonstrations did not turn out as expected, partially because of insufficient information by the teacher and partially because of the materials used in the presentations. An example of one such case provides an understanding of the learning situation arising from such circumstances. In a demonstration involving the inclined plane and the principle that the greater the distance an object is moved up an inclined plane, the less force is required, the final results showed tentatively that the principle was in error. Using three boards of varying lengths to represent the inclined plane, the amount of force required to move an object up the shortest board was 250 grams. The medium length board required 160 grams of force. However, the longest board required 175 grams of force to move the object up the inclined plane. According to the principle being developed, the last figure should have been the smallest of the three. This presented a problem to both the students and the teacher. However, after a lengthy discussion among the students, and the doing of the demonstration over again using a different object and being more careful, the problem was solved. The students finally realized that the boards were actually different, in that the two shortest boards were sanded smooth but unfinished, while the longest board was finished with varnish or shellac and possibly a wax coating. They decided that this finish caused a greater amount of friction between the inclined plane and the object being moved up it, therefore requiring a greater amount of force to raise the object up the plane.

This demonstration and the unexpected results provided the class with an ideal situation for real thinking. This was one of the first opportunities they had to do this type of work in the study. This situation showed them the need for critical thinking, and pointed out the various methods of going about the solving of a particular problem. They proved to be most exacting in their search for the answer to the problem.

Student responses. As a regular part of the class work, the students were required to write reports of some of the demonstrations shown as a part of this experimental study. Some of the students wrote with surprising clearness of thought concerning the scientific principles involved in the studies. Some excerpts from those reports are provided here as an indication of the type of thinking the students were doing. In the first demonstration given to the class several good reports were received. This demonstration involved the use of the inclined plane and is outlined above. In writing of the learnings from the demonstration, including the special problem encountered, one sixth grade girl said, "We found that the longer the inclined plane, the less force is necessary to raise an object. We also found out that friction interferes with the movement of an object up an inclined plane. The shorter the inclined plane, the more force is necessary to raise an object."

II. TEST SCORES

Test data. As a means of evaluating the effectiveness of the demonstration method of teaching science, three tests were administered to the group. The first test was given at the beginning of the school year to establish a basis for determining future gain. The results of this first test indicated a mean score of 24.72, out of a highest possible score of fifty. The range of scores went from a low of fourteen to a high of thirty-eight. The second test was administered to this same group at the end of the first semester, following ninety days of teaching science by the ordinary methods. A mean score of 28.04 resulted from this testing. This was an increase in mean score over the first testing of 3.32. These scores ranged from a low of nineteen to a high of forty-one. From this point, the experimental demonstration method of teaching was used to supplement the ordinary methods normally used in teaching science. At the end of the year the same test was again given to the group. This final testing resulted in a mean score of 33.44, which was a gain of 5.40 over the results obtained in the second testing and a total gain of 8.72 from the initial testing at the first of the school year. These final scores ranged from a low of twenty to a high of forty-five.

Table II, page 30, lists the individual scores obtained by the twenty-five students in the class for each of the three testings. Table III, page 31, shows the frequency distributions of the scores for each of the three testings.

TABLE II

TEST SCORES OF EXPERIMENTAL GROUP

Students	Test 1	Test 2	Test 3
1	25	24	34
2	24	32	38
3	20	29	35
4	28	34	42
5	25	30	31
6	37	41	45
7	17	26	31
8	17	19	20
9	25	27	31
10	22	27	33
11	28	36	39
12	23	22	36
13	14	26	35
14	19	29	31
15	23	21	20
16	24	21	30
17	24	29	36
18	30	33	38
19	24	23	30
20	21	23	30
21	19	23	20
22	35	37	43
23	30	31	35
24	38	39	43
25	26	19	30

TABLE III

DISTRIBUTION OF TEST SCORES

OF EXPERIMENTAL GROUP

	Frequency		
Distribution	Test 1	Test 2	Test 3
44-45	0	0	1
42-43	0	0	3
40-41	0	1	0
38-39	1	1	3
36-37	1	2	2
34-35	1	1	4
32-33	0	2	1
30-31	2	2	8
28-29	2	3	0
26-27	1	4	0
24-25	7	1	0
22-23	3	4	0
20-21	2	2	3
18-19	2	2	0
16-17	2	0	0
14-15	1	0	0
Mean Score=	24.72	28.04	33.44
Standard Deviation=	5.88	5.89	6.45

These distributions indicate roughly the increase in scores obtained by the group. The frequency with which the scores appeared is shown here, with the majority of the scores of the first test falling just below the mid-point of the distribution. The scores of the second test appear more spread out, but still mainly grouped around the mid-point of the distribution. On the third testing the scores appear above the mid-point of the distribution, generally, with the exception of three scores located near the bottom.

Figure 1, page 33, graphically portrays a comparison of the mean scores of the three testings. While a distinct gain appears between the first and second testings, a larger gain was shown in the results of the third test.

Significance. While it is apparent that gains did appear between the successive testings, Figure 1 fails to indicate whether these gains were significant enough to warrant any conclusions as to the value or effectiveness of the teaching method under study. From the data available three t-tests of significance were computed. The first two tests were to show whether the gains made between the first and second testings and the second and third testings were significant. The third t-test was a measure of the total gain made between the first and the third testings. The means of the three testings were used, since the t-tests

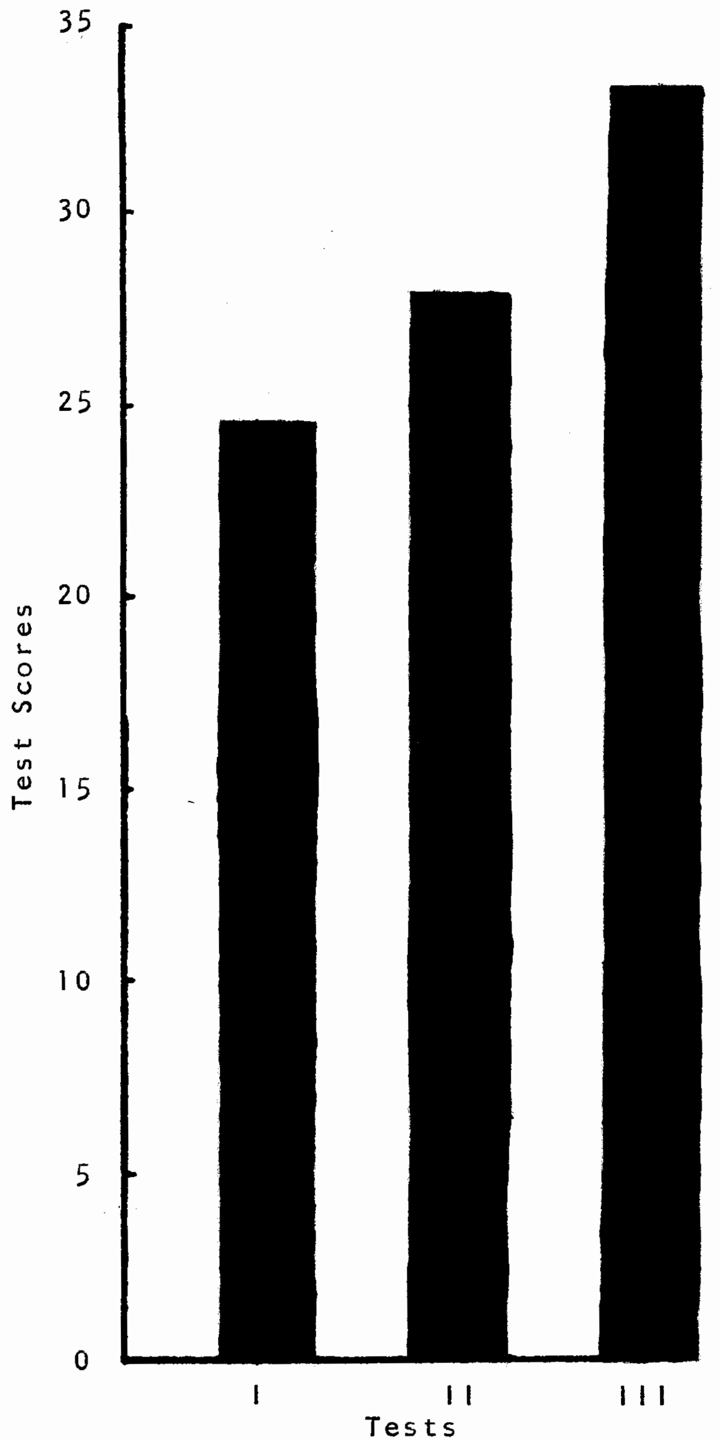

FIGURE 1

COMPARISON OF MEAN SCORES OF THREE TESTS were to determine if a significant difference existed between these correlated means.

The results of these t-tests indicated a t of 3.664 between tests I and II. A t of 6.976 was computed for tests II and III. Between tests I and III a t of 7.816 was determined. According to a standard table of values of t significant at the .01 and .05 levels of significance, a t value of 2.797 for twenty-four degrees of freedom is required for the .01 level of significance.[1] From these data the results obtained from the testing of the study group may be considered to be very significant.

Correlation with mental ability. The intelligence quotient scores for the students involved in this study are listed in Table I on page 18. There it is shown that the mean I.Q. of the entire group was 102.36, with a high I.Q. of 135 and a low I.Q. of 72. These I.Q. scores were correlated with the scores of Test I and the scores of Test III to determine whether a relationship existed between a student's intelligence and his ability to do critical thinking.

The results, using the formula for Pearson's r, indicated a correlation coefficient of .625 between the I.Q. and

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[1] Floyd L. Ruch and Neil D. Warren, Elementary Statistics in Psychology and Education, (Columbia, Missouri: Lucas Brothers, 1957), p. 89.

Test I scores. A correlation coefficient of .634 resulted between the I.Q. scores and the results of Test III.

A test of significance was applied to both these correlation coefficients to determine if they departed significantly from zero. For the coefficient of correlation between I.Q. and Test I, a t of 4.750 was computed. The correlation coefficient between I.Q. and Test III resulted in a t of 4.770. For twenty-three degrees of freedom, a t value of 2.807 is required at the .ol level.[2] From this, it is apparent that both these correlation coefficients have departed significantly from zero.

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[2] _Ibid._

CHAPTER V

CONCLUSIONS AND INTERPRETATIONS

The purpose of this study was to determine if the demonstration method of teaching science in the elementary school was effective in teaching the students to do critical thinking. A further objective of this investigation was to determine if there was a correlation between the intelligence of the students and their ability to think critically. It was also an objective of this study to determine if an effective device could be constructed to evaluate the critical thinking ability in elementary school students.

The combination fifth and sixth grade class served as a control group as well as an experimental group. Regular methods of teaching science were used during the first semester of the school year, and then the demonstration method was added during the second semester. Nearly all the demonstrations were teacher-conducted, though a few were shown by some of the better students in the class.

In order to evaluate the results of the teaching method, a Test of Critical Thinking was devised, since none existed for use at that level. This test consisted of fifty multiple choice items dealing with scientific principles taught during the year. However, the answers to the questions did not depend upon the retention of any facts or particular knowledge. All information necessary to the correct answering of the questions was contained in the test. The Test of Critical Thinking as used in this investigation was determined to be a reliable instrument, yielding reliability coefficients of .932 and .975 from two different methods of computation.

The Test of Critical Thinking was administered three times during the year. It was given at the beginning of the year to determine where each of the students was at the start, again at the middle of the year to establish growth to that point, and again at the end of the school year to determine total growth since the first of the year and the gain made since the middle of the year when the demonstration method of teaching was begun.

The results of the three tests provided mean scores of 24.72, 28.04 and 33.44, respectively. By applying t-tests to these means, it was determined that the students made a significant gain during the first semester in critical thinking ability. However, the t-tests which determined the difference between these means indicated that the group of pupils made an even greater significant gain during the second semester when the demonstration method of teaching science was used.

From these data it can be concluded that, <u>all other factors being equal, the demonstration method of teaching</u>

<u>science in the elementary school as it was used in this study is an effective means of teaching students to think critically</u>.

However, certain factors arise at this point to cast a shadow upon the above conclusion. First of all, the sample used in this study was quite small and might possibly not be indicative of the population as a whole. Also, it is generally agreed that on any specific day, some students will be mentally and physically handicapped by health or emotional problems and cannot concentrate to a point necessary to score realistically on any test. Other students may be exceptionally able to cope with testing on that particular day. In addition, the fact that it was necessary to administer the identical test three different times to the same students could alter the succeeding scores to a degree. Furthermore, the home environment, the students' friends, the teacher, and the methodology used in other subject areas may all affect the student's ability to think critically.

In view of the limitations of this study and the tentative conclusion fostered by the investigation, it is recommended that further investigation of the demonstration method of teaching critical thinking in elementary school science be conducted. Also, since so little research has been done into means of providing classroom teachers with evaluation instruments for such intangible objectives as critical thinking, it is further recommended that future studies attempt to improve the test used in this study and to devise better, more effective means of measurement.

The intelligence of the students in the class, as indicated by the I.Q. scores, was correlated with the results of the first testing at the beginning of the year and again correlated with the test results of the evaluation at the close of the school year. The results indicated that the student's intelligence was moderately related to his ability to think critically, as well as his ability to improve the ability to think critically. This does not entirely support the related findings of Teichman,[1] who concluded that there is a direct relationship between mental ability and the ability of a student to make conclusions. He did arrive at a similar conclusion, however, when he said that mental ability does not seem to have much affect on the ability of students to improve the skill of making conclusions. Further investigation of this problem of the relationship between mental ability and the ability to think critically is needed.

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[1]Louis Teichman, "The Ability of Science Students To Make Conclusions," Science Education, 28 (December, 1944), pp. 268-279.

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APPENDIX A

SCIENCE UNITS AND PRINCIPLES[1]

1. <u>The Earth and its Surface</u>:
    a. The earth is very old and has undergone great changes during its lifetime.
    b. The earth's surface is made of water, soil, and rocks in many different forms.
    c. Many agencies break up and wear away rocks.
    d. Many forces are continually changing the surface of the earth.
    e. Living things could not exist on the earth without soil.
    f. There are still many things concerning the various phenomena on the earth which scientists cannot completely explain.

2. <u>The Air and the Weather</u>:
    a. The ocean of air that surrounds us is essential to life.
    b. Changes in the conditions of the air determine the weather.
    c. The movements of "highs" and "lows" bring about changes in weather conditions.
    d. Wind movements over the earth's surface follow a definite pattern.
    e. Weather forecasting depends on knowledge of air movements and an understanding of the causes of different kinds of weather.
    f. Weather conditions can be forecast with considerable accuracy by the use of instruments.

3. <u>Plant Growth</u>:
    a. All plants need certain essentials in order to stay alive and grow.
    b. Plants manufacture food essential to the existence of living things on the earth.
    c. Plants reproduce themselves in several ways.

4. <u>Time and Seasons</u>:
    a. The movement of the earth around the sun and the tilt of the earth's axis cause our seasons.
    b. The movement of the earth on its own axis causes time changes.

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[1] Though all the units were taught, only selected principles were included in the study.

5. The Human Body and How It Works:
    a. Food is dissolved or chemically changed by digestion into a soluble state before it is used by the body.
    b. Oxygen is essential for the production of energy in the body, and carbon dioxide must be eliminated.
    c. The various groups of organs in the body work together as a unit.
    d. Foods differ in their constituents and thus supply the various requirements to the body.

6. Matter and Chemical Changes:
    a. All matter is composed of the elements.
    b. Elements are composed of molecules and atoms.
    c. When chemical changes occur, new materials are formed which are different in their characteristics from the substances which united to produce them.
    d. Chemical changes are important in our lives.

7. Machines and How They Work:
    a. Machines make work easier. Some gain force, some distance, and some speed.
    b. Simple machines do not gain force, distance, and speed at the same time.
    c. Energy is the capacity to do work, and it exists in a number of forms.
    d. Work is done when a force is exerted through a distance.
    e. All machines lose some of their efficiency because of friction.

8. Magnetism and Electricity:
    a. An electric current is believed to be the flow of particles called electrons.
    b. Current electricity is produced by cells and generators.
    c. Materials vary in the efficiency with which they conduct electricity.
    d. Electricity and magnetism are interrelated forms of energy.
    e. Man has learned to make electricity do work for him.
    f. Electrical energy may be transformed into other forms of energy.

9. Aviation:
    a. Balloons and dirigibles are filled with lighter-than-air gases.

b. Airplane wings create unequal air-pressure areas to enable the plane to rise.
c. There are many types of aircraft designed for specific purposes.
d. Jet planes are propelled by air.

10. <u>First Aid</u>:
a. Injury to the body requires instant care and attention.
b. Different injuries require different care.
c. Grave dangers may result from improper care of injuries.

APPENDIX B

LIST OF DEMONSTRATIONS

Many demonstrations were used during the second portion of the study. While some of these demonstrations were quite simple and used only ordinary materials that were at hand, other demonstrations became somewhat more complex and required considerably more equipment. Below is a partial list covering most of the major demonstrations used in this study.

Magnets attract some materials, but not others.

Like magnetic poles repel each other; unlike poles attract each other.

Magnets are surrounded by a magnetic field.

Current electricity flows in a closed metallic circuit.

Some substances conduct electricity while others do not.

A current of electricity has a heating effect.

Fuses prevent wires from becoming dangerously hot.

A current of electricity may be used to produce magnetism.

A current of electricity has a magnetic effect.

Vertical rays of sunshine give more energy than slanting rays.

Plants need light and grow towards the source of such light.

Plants need light, air and water.

Green plants make starch when in sunshine.

Roots seek water.

Air expands when heated.

Hot air rises.

Warm air can hold more moisture than cold air.

Air exerts pressure.

Air presses because it has weight.

Low pressure areas exist in the atmosphere.

Rain is a part of the water cycle.

A cloud can be artificially produced.

Mountains have been formed by slow movements of the earth's crust.

Clouds are made from the water in the air.

The production of carbon dioxide is a chemical change.

Some combinations of chemicals are mixtures.

An inclined plane makes work easier.

A lever makes work easier.

APPENDIX C

TEST OF CRITICAL THINKING

This is a test to see how well you can think. You should read each question and then think carefully before marking an answer. You should mark an answer for every question. Do not leave any questions blank. <u>Answer all questions</u>! For each question there is one <u>best</u> answer. Mark only one answer for each question. No questions will be answered after you begin the test. If you have a problem raise your hand and the teacher will help you. Do not worry if you do not completely understand the questions. All the information you need to answer the questions is given to you in each question. Mark your answers using only the information given in the questions.

DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO BEGIN

PART I

In the following questions, two true statements are given. Put a circle around the letter before the sentence that <u>best</u> makes a true statement according to the two true statements given at the beginning of the question.

1. An acid will neutralize a base. Vinegar is an acid.
    a. Vinegar will neutralize a base.
    b. Acids are called vinegar.
    c. An acid will neutralize vinegar.

2. Mushrooms are plants. Some plants are green.
    a. Mushrooms are green.
    b. All plants are mushrooms.
    c. Some plants are not green.

3. A lever is a simple machine. A screw is a simple machine.
    a. A screw is a lever.
    b. Some levers are screws.
    c. Some simple machines are screws.

4. A jet plane is powered by compressed air. Some guided missiles are powered by compressed air.
    a. Jet planes are guided missiles.
    b. Some guided missiles are jet planes.
    c. Compressed air powers all guided missiles.

5. The body uses sugar to provide energy. Starch can be changed to sugar by the body.
    a. A person should eat all starchy foods.
    b. A person can use starch for energy.
    c. A person should not eat starchy foods.

6. Jet planes are better for some purposes than regular airplanes. There are more jet planes now than there were ten years ago.
    a. In ten years all planes will be jets.
    b. Regular airplanes are not being built anymore.
    c. More jet planes will probably be built in the next ten years.

7. Young mountains are tall and pointed. The Appalachian Mountains are short and rounded.
    a. The Appalachian Mountains are tall and pointed.
    b. The Appalachian Mountains are old.
    c. The Appalachian Mountains are young.

8. Serious burns are called third degree burns. Some sunburn is second degree.
   a. Sunburn is one of the most serious kinds of burns.
   b. All sunburn is third degree.
   c. Some sunburn is first degree.

9. There is a three-hour difference in the time between Eastern and Pacific Standard Time. There are four time zones in the United States.
   a. When it is noon in Seattle, it is 3 a.m. in New York.
   b. When it is 6 p.m. in Seattle, it is 9 p.m. in New York.
   c. When it is midnight in Seattle, it is 3 p.m. in New York.

10. Plants need carbon dioxide to grow. There is carbon dioxide in the air.
   a. Without carbon dioxide plants will die.
   b. If there is no carbon dioxide, plants will get it elsewhere.
   c. Plants will still grow when there is no carbon dioxide.

11. All magnets will pick up iron. Some metals are iron.
   a. All magnets will pick up metals.
   b. Some magnets will pick up metals.
   c. All magnets will pick up some metals.

12. All rainwater was once on the earth. Some rainwater was once in the ocean.
   a. All rainwater was once in the ocean.
   b. Some rainwater was once on the land.
   c. No rainwater was ever on the land.

13. A chemical change produces something new. Rust is the result of a chemical change.
   a. Chemical changes produce rust.
   b. Some rust is not the result of a chemical change.
   c. Some chemical changes result in rust.

14. A tree takes in water at its roots. Some trees have leaves that change color.
   a. All trees that have leaves that change color take in water at their roots.
   b. All trees that take in water at their roots have leaves that change color.
   c. All trees take in water at their roots only when their leaves change color.

15. The earth is many years old. Some parts of the earth are changing.
    a. Some parts of the earth are not old.
    b. All parts of the earth are changing.
    c. All parts of the earth are old.

16. An animal breathes in oxygen. An animal breathes out carbon dioxide.
    a. An animal needs carbon dioxide to live.
    b. An animal needs oxygen to live.
    c. An animal needs both oxygen and carbon dioxide to live.

17. Bacteria are very small things. Bacteria sometimes produce disease.
    a. Disease is produced by some very small things.
    b. Bacteria always produce disease.
    c. Very small things produce bacteria.

PART II

In the following questions, an experiment is described and some possible statements are made about the experiment. Put a circle around the letter before the statement that best tells the truth about the experiment.

1. When an artery is cut the bleeding may be stopped by tying a tourniquet (a tight bandage) between the cut and the heart. This shows that:
    a. blood in the artery is flowing away from the heart.
    b. arterial bleeding is dangerous.
    c. when an artery is cut, it will bleed.
    d. blood in the arms and legs flows downward.

2. A student placed a geranium plant under a bell jar and filled the jar with the gas carbon dioxide. He placed a burning splinter in the jar and the flame went out. He sealed the jar completely, and placed it, with the plant, in the sunlight. The next day he again inserted a burning splinter and this time it continued to burn. He knows that the gas oxygen helps burning. This would show that:
    a. plants use carbon dioxide.
    b. the carbon dioxide escaped.
    c. the flame was put out by the carbon dioxide.
    d. plants use carbon dioxide and give off oxygen.

3. A student placed a bar magnet on a pile of iron filings and noticed that most of the filings were held at the ends of the magnet, with few filings in the center. This would show that:
   a. magnets attract iron filings.
   b. the ends of a magnet are called the poles.
   c. horseshoe magnets are stronger than bar magnets.
   d. magnetism is strongest at the ends of a bar magnet.

4. Fish need oxygen in order to live. Fish placed in a tank of water containing plants continue to live, but fish placed in plain water will die after a few days. This would show that:
   a. the plants supply the fish with oxygen.
   b. fish need oxygen in order to live.
   c. there is something in water that kills fish.
   d. fish in water with plants do not need oxygen.

5. A student found by experiment that a magnet can attract iron, steel, and nickel, but cannot attract aluminum, tin, copper and brass. He tried the magnet on a tin can, and found that it was attracted. This would show that:
   a. the tin can is made of steel.
   b. impure tin may be attracted to a magnet.
   c. the tin can contains nickel.
   d. the tin can is not made entirely of tin.

6. Air creates a pressure by pushing with its weight on things. A student put some hot water in a jar and then sealed the jar tight with a light metal lid like that used in canning foods at home. After a short while, the lid showed a small dent in the middle. This would seem to show that:
   a. someone hit the top of the lid with something heavy.
   b. the air pressure was greater inside the jar.
   c. the air pressure was less inside the jar.
   d. the air pressure was the same on both sides of the jar.

7. If water runs over a rock for a long time the rock will eventually break down into soil. A student put a rock in the sink and ran water over it for three hours, but nothing happened. This shows that:
   a. the rock in the sink was harder than other rocks.
   b. some rocks are softer than water.
   c. the water in the sink was too soft.
   d. the rock in the sink did not have water run on it long enough.

8. When iodine is put with starch, there is a blue-black color. One student experimented by putting iodine on a piece of bread. The bread became blue-black in color. He then mixed some bread with some saliva from his mouth. After a while he put some iodine on the second bit of bread, but it only turned a yellow color. This might show that:
    a. starch is changed to something else in the mouth.
    b. the bread still contained starch.
    c. he put too much iodine on the second bit of bread.
    d. starch does not stay in bread very long.

9. Electricity must travel in a complete circuit, or circle. A boy once put two wires on a dry cell. One wire he fastened to a door bell buzzer. Then he put another piece of wire on the bell. The two ends of the wires he put in a glass of water from the faucet, fixing them so they wouldn't touch, and the bell rang. This shows that:
    a. he didn't have a complete circuit for the electricity.
    b. water will carry, or conduct, electricity.
    c. the wires were not covered with insulating material.
    d. someone had pushed the doorbell outside.

10. A student planted different types of seeds in five large pots. Two of these pots contained good soil and the other three contained the same soil but with all potassium salts (a type of mineral) removed. The plants in the good soil grew well and developed fully, but the plants in the other three pots were very small and eventually died. This would seem to show:
    a. plants need potassium salts in order to begin growth.
    b. the plants needed more soil.
    c. potassium salts absorb water.
    d. potassium salts are necessary for the full development of plants.

11. A small boy once got into the medicine chest when his mother wasn't looking and drank a small bottle of poison. When his mother found out what he had done she fed him soapy water and he was all right. The soapy water:
    a. made him vomit, or throw up, the poison from his stomach.
    b. took the poison out of the medicine he had swallowed.
    c. killed the bacteria in his stomach.
    d. made him hungry, so he could eat good food for lunch.

12. A farmer was digging stumps out of a field before plowing it. The stump was so large that even after he cut the roots and dug all around it, he still couldn't push it out. Finally, he got a long piece of lumber and put one end under the stump. He put a big rock under the wood at the edge of the hole and then he pushed down hard on the other end of the lumber and the stump came out. This would show that:
    a. after the farmer had rested he was stronger.
    b. the stump finally broke loose from the ground by itself.
    c. the piece of lumber acted as a wedge to break the stump free.
    d. the piece of lumber acted as a lever to increase the farmer's strength.

13. When iodine is added to starch, a blue-black color is formed. Some iodine was added to milk, and the color became yellow. This shows that:
    a. milk contains sugar.
    b. milk contains starch.
    c. iodine can not be used to test for starch in milk.
    d. milk does not contain starch.

14. A salesman drove his car from Spokane to Butte, Montana in 14 hours just as he planned. There is a one-hour difference of time between Mountain Standard and Pacific Standard Time. Washington State does not approve Daylight Saving Time, but the week before the salesman went on the trip, Montana went on Daylight Saving Time, which moves all time in an area one hour ahead. When the salesman arrived in Butte at 3 p.m. according to his watch, he found he was two hours late for his appointment. This shows that:
    a. he drove too slow during the trip.
    b. his watch had stopped two hours before.
    c. his appointment had been for 3 p.m. Mountain Daylight Time.
    d. the time was really only 2 p.m. Mountain Daylight Time.

15. The gas carbon dioxide turns limewater milky. A student burned a piece of wood in each of two bottles. Then he placed some water in one of the bottles and some limewater in the other bottle, and shook both. Nothing happened to the water, but the limewater turned milky. This shows that:
    a. carbon dioxide was present in the bottle.
    b. the piece of wood contained carbon dioxide.
    c. carbon dioxide is formed when wood burns.
    d. carbon dioxide turns limewater milky.

16. A pilot was flying over the mountains one day when suddenly there was a high peak in front of him. He imediately pressed down on the right rudder pedal and pulled back on the control stick. The plane climbed to the right and missed the big peak. This might show that:
    a. the wind blew harder suddenly and blew the plane up and over.
    b. the rudders help to turn the plane.
    c. the control stick helps to turn the plane.
    d. the rudders and control stick make the plane climb.

PART III

The statements in the following questions are true. Put a circle around the letter before the best answer that completes the sentence.

1. The turning of the earth on its axis makes night and day. The sun does not move. If the earth makes seven complete turns on its axis:
    a. three days and four nights will have passed.
    b. four days and three nights will have passed.
    c. seven days and nights will have passed.
    d. fourteen days and nights will have passed.

2. The motion of the earth around the sun and the tilt of the earth on its axis cause the different seasons. When it is summer in the northern hemisphere, it is winter in the southern hemisphere. The men camped at the south pole will celebrate Christmas when it is:
    a. spring there.
    b. summer there.
    c. fall there.
    d. winter there.

3. Wind moves from an area of high pressure to an area of low pressure. If the air pressure is low in Portland, high in Seattle and low over the Pacific Ocean:
    a. a wind will blow from Portland to Seattle.
    b. a wind will blow from Seattle to Portland.
    c. a wind will blow from Portland to the Pacific ocean.
    d. a wind will blow from the Pacific Ocean to Portland.

4. A wrench is a type of lever or simple machine that makes work easier. If a plumber who has a hard time loosening a water pipe takes another long piece of pipe and puts it over the handle of the wrench:
    a. he has to work harder because the pipe makes the wrench heavier.
    b. he has to work just as hard as before because the pipe makes no difference.
    c. the pipe makes his work easier though he has to push the pipe further.
    d. the pipe makes his work easier because its weight helps to loosen the water pipe.

5. A bandage is usually used to keep a cut or other injury clean. Bacteria that get into an open cut or injury in the skin can cause infection and make it sore. If a cut on the finger is not bandaged:
    a. the cut will stay clean.
    b. the cut may become infected.
    c. the cut will keep out bacteria.
    d. the cut may not stop bleeding.

6. An acid and a base mixed together will produce carbon dioxide, a gas. Limestone is a base. To produce the gas carbon dioxide, it is necessary to:
    a. mix a base and limestone together.
    b. mix an acid and limestone together.
    c. both a and b.
    d. neither a nor b.

7. A plant needs light, water and the gas carbon dioxide in order to manufacture food. If a plant is well watered and is located in a garden with lots of air, it will:
    a. manufacture food all the time.
    b. manufacture food only during the day.
    c. manufacture food only at night.
    d. do none of these.

8. The blood in the body carries food and oxygen to the different parts of the body. Blood that is bright red contains oxygen. If a person is cut in the chest and the blood that comes from the cut is bright red, one can say that:
    a. the blood is going to the parts of the body.
    b. the blood is going to the lungs.
    c. the blood is returning to the heart from the legs.
    d. The blood is going away from the brain.

9. Fainting is caused by a lack of enough blood in the brain. If you begin to feel faint, the best thing to do is:
   a. stand on your head.
   b. lie down.
   c. forget about it.
   d. call a doctor.

10. A plant will bend toward light. If a plant is exposed to light only on one side for a few days, then is exposed to full light:
   a. the plant will remain straight.
   b. the plant will bend and then straighten.
   c. the plant will remain bent.
   d. the plant will remain straight and then bend.

11. A volcano results when hot melted rock and hot gases collect inside the earth and build up enough pressure to break through a weak place in the surface of the earth. Lava is hot melted rock that comes from the volcano. If an old volcano has not been active for many years and the lava has hardened so there is no longer a break in the earth's surface at that place, the melted rock and hot gases that build up great pressures inside the earth will:
   a. not be able to break through the earth's surface.
   b. cool off and let the pressure go down.
   c. build enough pressure to break through the hardened lava.
   d. move to another old volcano to break through.

12. A pulley makes work easier. When two pulleys are used together, it is possible to life a weight one foot by pulling the attached rope twice as far. If a farmer uses two pulleys to lift a bale of hay forty-three feet up to the top of a stack, he will need:
   a. 43 feet of rope to pull.
   b. 86 feet of rope to pull.
   c. 129 feet of rope to pull.
   d. 172 feet of rope to pull.

13. An electro-magnet will pick up more iron filings when there is more power or when there are more coils of wire around the magnet. Suppose a magnet with 50 coils of wire is connected to two dry cells for power. If the magnet is to pick up less iron filings it will be necessary to:
   a. wrap more coils of wire around the magnet.
   b. decrease the number of dry cells.
   c. both a and b.
   d. neither a nor b.

14. A plant loses water by evaporation from its leaves. Water evaporates from all surfaces under normal conditions. If a plant in a pot weighs 5 pounds and then is allowed to sit for several days without being moved, and then weighs the same as before, it can be said that:
    a. water has evaporated from the plant.
    b. water has evaporated from the pot.
    c. water was added to the pot.
    d. none of these.

15. A cloud is made up of water vapor. Rain is condensed water vapor. Cold condenses water vapor. If, on a cloudy day, the air pressure increases, which will lower the clouds and warm them, then:
    a. it will rain.
    b. it will not rain.
    c. the clouds will disappear.
    d. the clouds will stay.

16. Cold causes water vapor to condense. Heat causes water to evaporate. If a pan of water is partly covered with a sheet of glass that has ice cubes on it and the pan of water is then heated:
    a. the water in the pan will evaporate.
    b. water vapor will collect on the bottom of the glass.
    c. both a and b.
    d. neither a nor b.

17. Some jet planes can fly from the West Coast to the East Coast of this country in about four hours. A regular airliner, not a jet, flies the same distance in about twelve hours. If a regular airliner and a fast jet plane took off from Los Angeles, California at the same time and headed for Washington, D. C., the jet plane would:
    a. be in Washington before the airliner was one-fourth the way.
    b. be in Washington before the airliner was one-third the way.
    c. be in Washington the same time as the airliner.
    d. be in Washington after the airliner.

APPENDIX D

TABLE IV

TEST SCORES USED TO DETERMINE

TEST RELIABILITY

Students	Test I	Test II[1]
1	23	20
2	23	31
3	24	28
4	20	23
5	9	11
6	38	37
7	28	29
8	29	30
9	14	17
10	11	17
11	39	37
12	17	18
13	34	31
14	28	32
15	28	32
16	23	24
17	19	20
18	9	18
19	23	26
20	30	31
21	21	20
22	17	16
23	29	26
24	22	22
25	17	18
26	13	21
27	28	30
28	28	32

[1]The second testing of this group of students was administered exactly one week after the administering of the first test and under identical conditions.

TABLE V

DISTRIBUTION OF TEST SCORES USED TO DETERMINE TEST RELIABILITY

Distribution	Frequency Test I	Test II
39-40	1	0
37-38	1	2
35-36	0	0
33-34	1	0
31-32	0	6
29-30	3	3
27-28	5	1
25-26	0	2
23-24	5	2
21-22	2	2
19-20	2	3
17-18	3	5
15-16	0	1
13-14	2	0
11-12	1	1
9-10	2	0
Mean Score=	23.00	24.89
Standard Deviation=	7.6	6.8